Salient Results OSTST 2017-2020:

Australian Altimetry: From Precision Sea Level to Near-Real Time Delivery and Applications

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UNIVERSITY of TASMANIA AUSTRALIA

CSIRO

IMOS Integrated Marine Observing System

Ocean Surface Topography Science Team Meeting

October 19-23, 2020

Virtual Meeting

Overview

Work Package 1: Calibration and Validation

- Continuation of the long term absolute validation facility in Bass Strait.
- Development to incorporate multi-missions: Jason-series, Sentinel-3A and Sentinel-3B.

Work Package 2: Changes in Mean Sea Level

- Production and interpretation of the GMSL climate data record.
- Validation of altimetry against tide gauges, assessment of systematic error and vertical land motion.

Work Package 3: Real Time Oceanography and Applications

- Continuation of the Australian real-time multi-mission gridded sea level analysis system
- Visualisation with other satellite (SST, Chlorophyll, waves) and in-situ data, assimilation into ocean models and outreach to end-users.

Work Package 4: Coastal Altimetry and Preparation for SAR Altimetry

- Preparation for Sentinel-6 and SWOT.

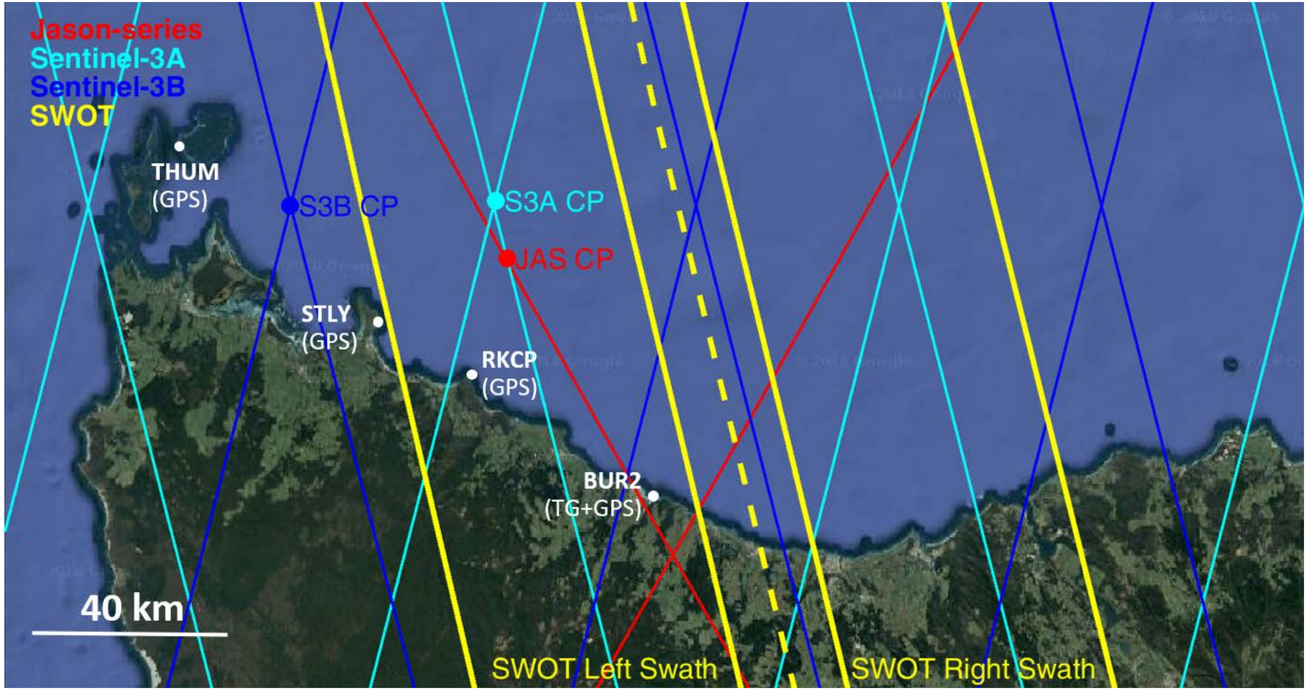
Highlights

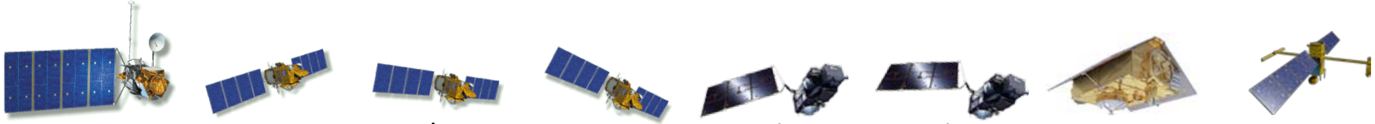
WP1: Calibration and Validation

WP1:

Cal/Val Highlights from the Bass Strait Validation Facility

- Continued operation of the Southern Hemisphere Bass Strait validation facility – sustained in situ observations to provide confidence in the altimeter climate record.
- Enhanced to now service Jason-series, Sentinel-3A and Sentinel-3B missions.
- Preparation for Sentinel-6 and SWOT underway with several improvements to in situ instrumentation (GNSS/INS buoys, CWPIES).





TOPEX / Poseidon Aug 1992

Jason-1 Dec 2001

OSTM/Jason-2 June 2008

Jason-3 Jan 2016

Sentinel-3A Feb 2016

Sentinel-3B Apr 2018

Sentinel-6 / Michael Freilich Nov 2020 (planned)

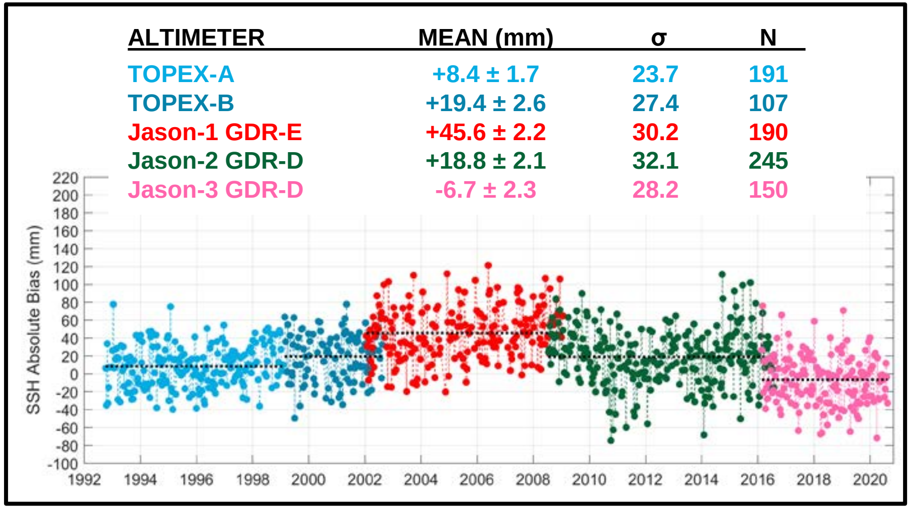
SWOT Feb 2022 (planned)

WP1: Cal/Val Highlights

- Ongoing cycle-by-cycle comparison of altimeter SSH against in situ SSH to iteratively assess “whole of system” accuracy and precision -> a key part of the altimeter mission design.

- All mission biases now insignificantly different from zero with the exception of Jason-1 which remains unexplained from the Bass Strait, Corsica and Gavdos validation sites.

- Improved precision of new S-3A and S-3B SAR observations are readily apparent from comparison against Bass Strait in situ data (Standard deviation of ~21 vs ~31 mm SAR vs PLRM respectively).



WP1: Cal/Val Highlights

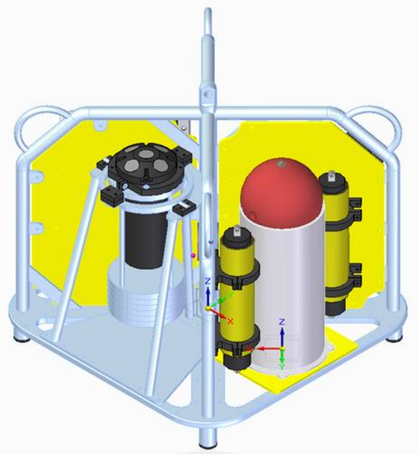
- Validation requirements for future missions require improved in situ instrumentation and understanding of systematic error sources.
- GNSS equipped buoys:
  - Effect of currents/waves on mean buoyancy position.
  - Effect of antenna orientation.
  - Zhou et al, *Remote Sensing*, 2020.
- Current, Waves, Pressure Inverted Echo Sounders (CWPIES):
  - Demonstrated approach yielding accurate SSH across high and low frequencies.
  - Complements GNSS/INS approach well to advance our understanding of small signals in Bass Strait.

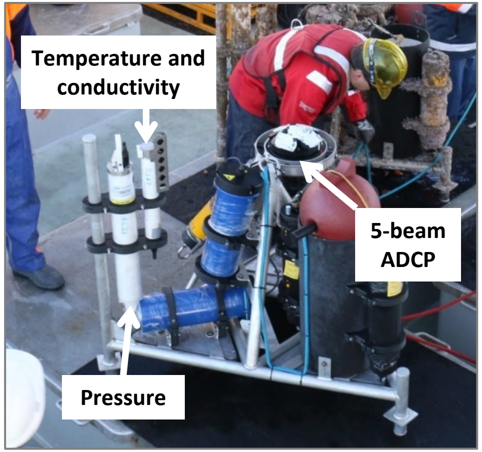

remote sensing 2020 MDPI

Article

GNSS/INS equipped buoys for altimetry validation – lessons learnt and new directions from the Bass Strait validation facility

Boye Zhou [1*], Christopher Watson [1], Benoit Legresy [2], Matt A. King [1], Jack Beardsley [1], Alistair Deane[1]





Highlights
WP2: Mean Sea Level

WP2: GMSL Highlights

- Identification of small but significant systematic errors in the early part of the GMSL record (Watson et al. *NCC*, 2015). Explains previous deceleration in the GMSL record.
- Quantification of an emerging acceleration now evident over the altimetry era. Improved sea level budget closure (Chen et al. *NCC*, 2017).
- Improved understanding of the uncertainty associated with validating the GMSL record (Watson et al. *ASR*, 2019). We show that approximately 2.9 years of Jason-series data is required to reach a *validation* uncertainty of ±1 mm/yr (1σ).

nature climate change LETTERS
PUBLISHED ONLINE: 11 MAY 2015 | DOI: 10.1038/NCLIMATE2635

Unabated global mean sea-level rise over the satellite altimeter era

Christopher S. Watson[1]*, Neil J. White[2], John A. Church[2], Matt A. King[1,3], Reed J. Burgette[4] and Benoit Legresy[2]

nature climate change LETTERS
PUBLISHED ONLINE: 26 JUNE 2017 | DOI: 10.1038/NCLIMATE3325

The increasing rate of global mean sea-level rise during 1993–2014

Xianyao Chen[1]*, Xuebin Zhang[2]*, John A. Church[3], Christopher S. Watson[4], Matt A. King[4], Didier Monselesan[2], Benoit Legresy[2] and Christopher Harig[5]

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Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research xxx (2019) xxx–xxx
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

On the uncertainty associated with validating the global mean sea level climate record

Christopher S. Watson [a,*], Benoit Legresy [b], Matt A. King [a]
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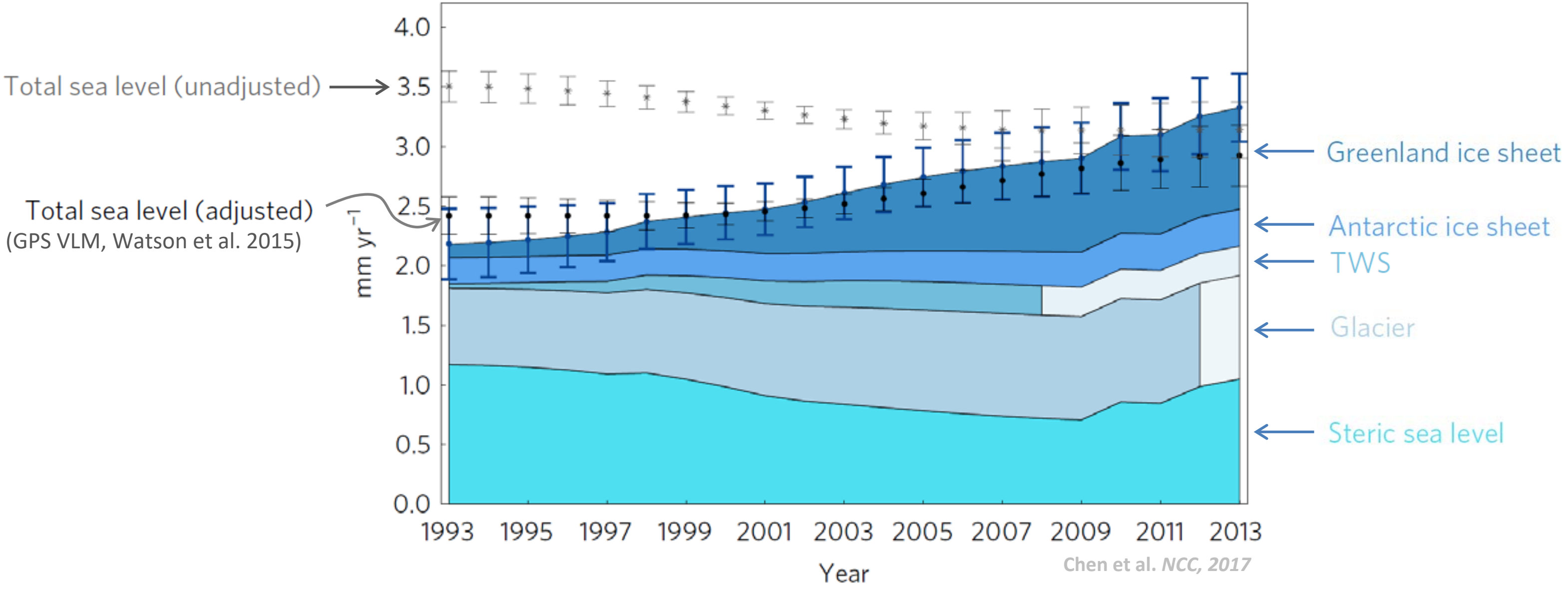
WP2: GMSL Highlights

- Key result from Chen et al. *NCC*, (2017): time variable closure of the sea level budget against "unadjusted" and "adjusted" GMSL from Watson et al. *NCC*, (2015). Brought the issues related to TOPEX at the start of the GMSL record into focus.



Chen et al. *NCC, 2017*

WP2: GMSL Highlights

- Importance of noise model selection in trend uncertainty (Royston et al. *JGR*, 2017). AR(1) rarely suitable.
- Noise model not dependent on accounting for ENSO and PDO in the regression.
- Identification of key regions where the observed trend emerges from intrinsic noise across Indian and Pacific oceans.

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1002/2017JC013655

Key Points:
- Accounting for ENSO and PDO variability does not affect the type of noise model that best describes the sea-level trend residual
- Standard errors may be under (or over) estimated by assuming an AR(1) noise model when compared to a more realistic noise model
- The observed trend in the satellite altimetry era emerges from the intrinsic noise for some key locations in the Indian and Pacific Oceans

Sea-Level Trend Uncertainty With Pacific Climatic Variability and Temporally-Correlated Noise

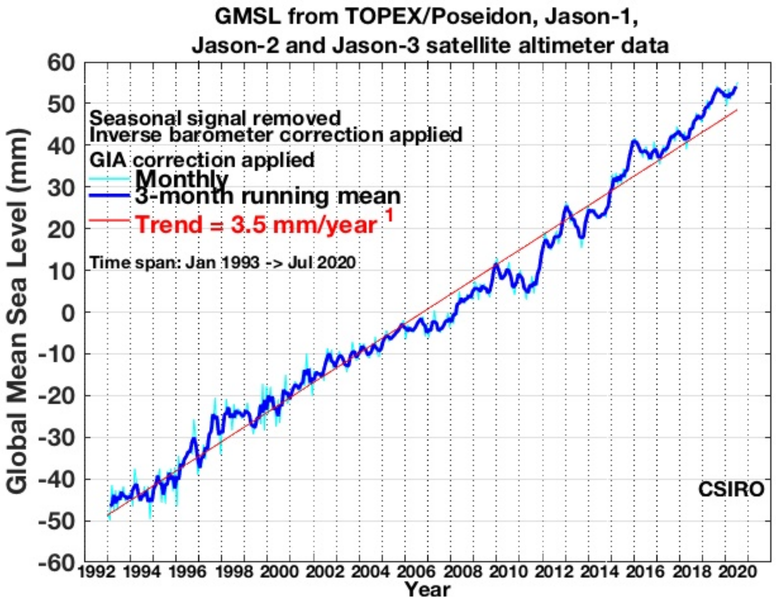
Sam Royston[1], Christopher S. Watson[1], Benoit Legrésy[2,3], Matt A. King[1], John A. Church[4], and Machiel S. Bos[5]

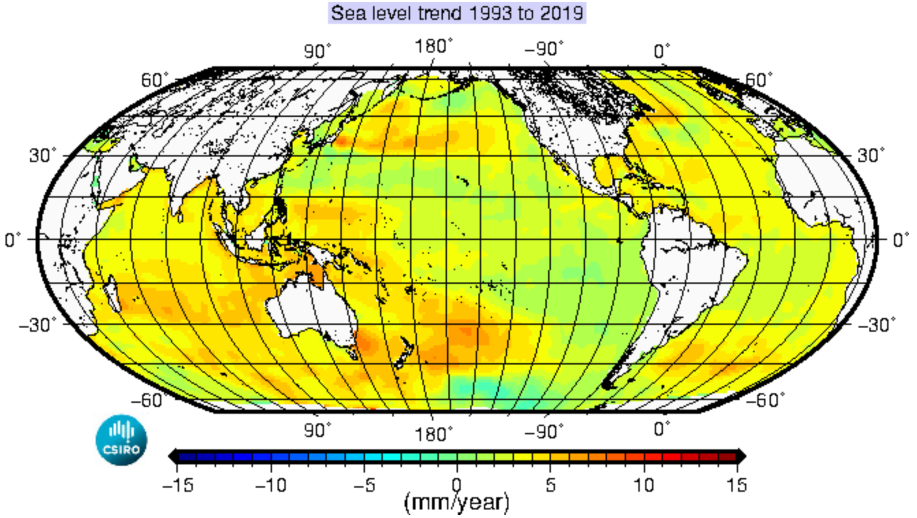
[1]Discipline of Geography and Spatial Sciences, University of Tasmania, Hobart, TAS, Australia, [2]CSIRO Oceans and Atmosphere, Hobart, TAS, Australia, [3]Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, TAS, Australia, [4]Climate Change Research Centre, University of New South Wales, Sydney, NSW, Australia, [5]Space and Earth Geodetic Analysis Lab, University of Beira Interior, Covilhã, Portugal

Abstract Recent studies have identified climatic drivers of the east-west see-saw of Pacific Ocean satellite altimetry era sea level trends and a number of sea-level trend and acceleration assessments attempt to account for this. We investigate the effect of Pacific climate variability, together with temporally-correlated

WP2: GMSL Highlights

- Various updated sea level products available from the CSIRO page: https://www.cmar.csiro.au/sealevel/sl_hist_last_decades.html



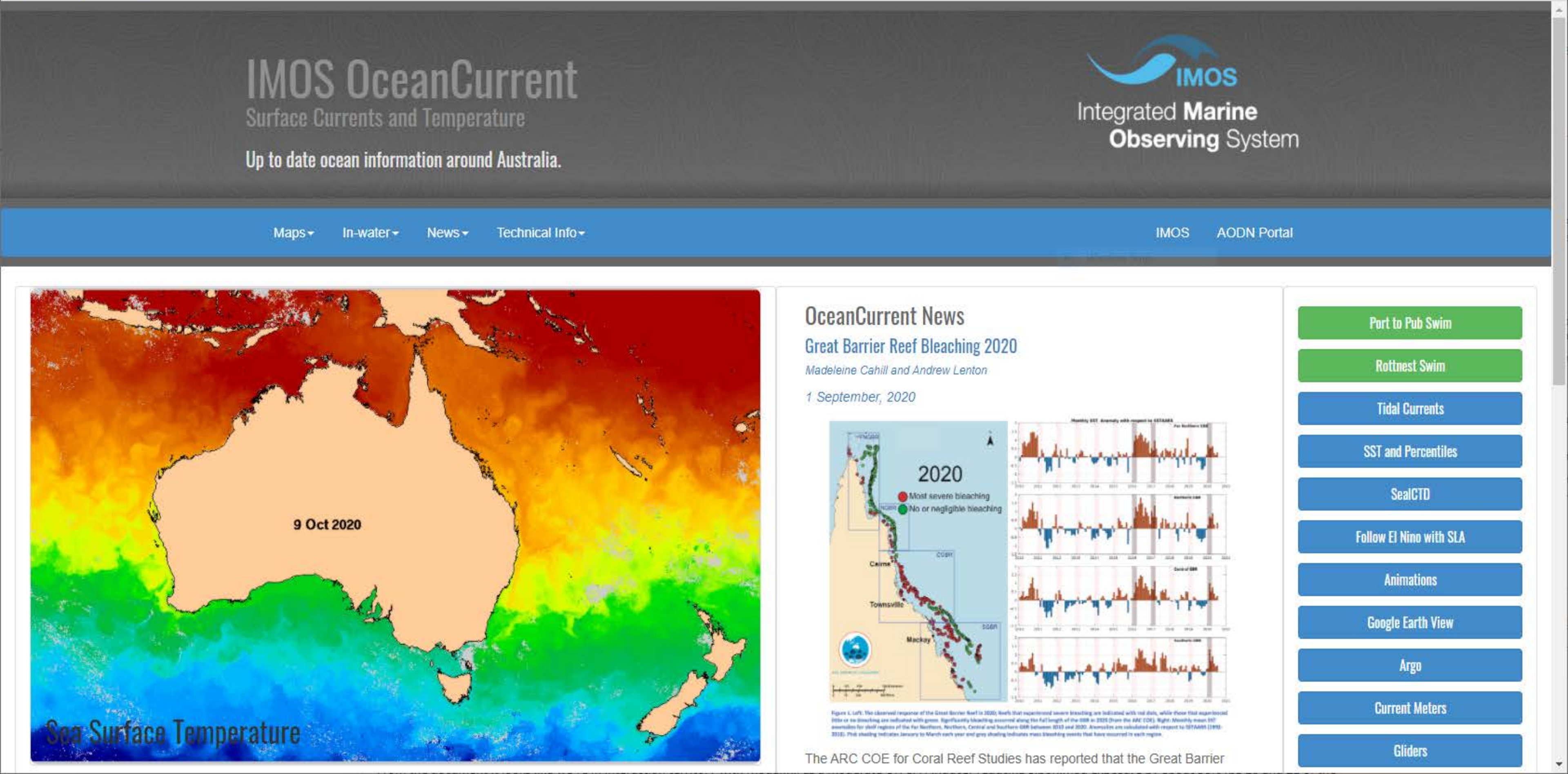


Highlights

WP3: Real Time Oceanography and Applications

http://oceancurrent.imos.org.au/

CSIRO lead (Cahill et al)



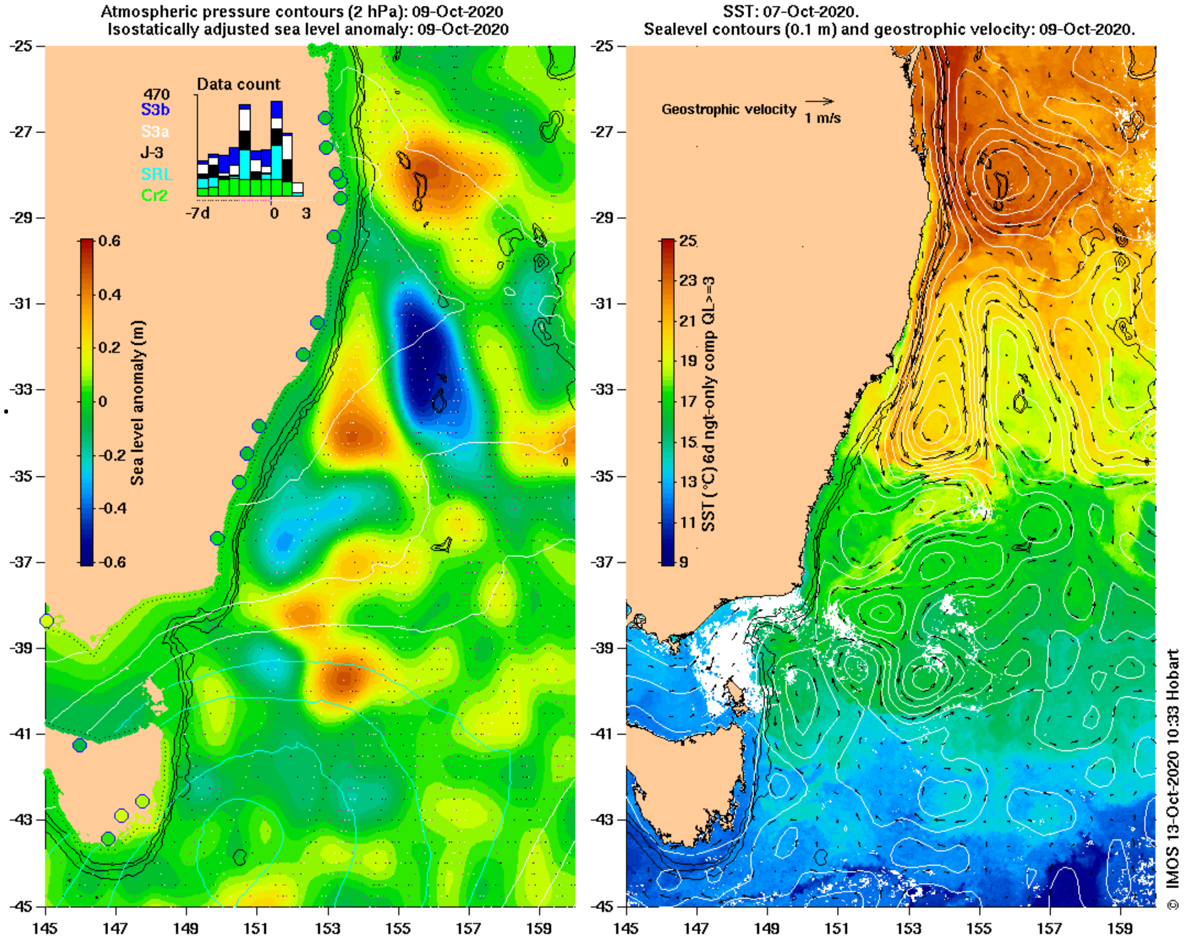
OceanCurrent

CSIRO lead (Cahill et al)

Ongoing enhancements to the Australian *OceanCurrent* website with IMOS support.

Up to date ocean information around Australia: http://oceancurrent.imos.org.au/

- SLA, SST, Ocean Colour, Radar, Gliders, …
- Tidal currents, Argo…
- Choose your own date and region, generate animations…
- Interesting news stories…
- Wave data coming soon…
- Large and diverse user base from scientific to generalist…



Waves – New IMOS sub-facility

Collaboration between CSIRO and University of Melbourne

CSIRO Component:

- SAR directional wavenumber swell spectra.
- Australasia regional focus (currently).
- 2015-present.
- Delayed mode + NRT component.
- Daily along-track netCDF files recently published on AODN (see over).

University of Melbourne Component:

- Altimeter Hs and Wspd.
- Global, 33-year, multi-mission (13).
- Calibrated against global buoy dataset ndbc, ECMWF.
- 1 x 1 deg tiled netCDF files.

Waves – Data and Papers

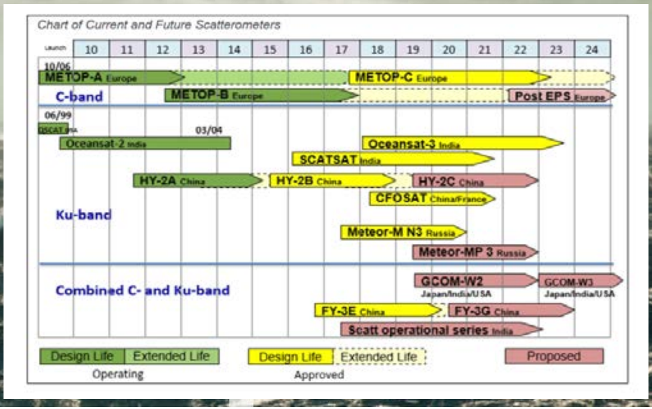
Datasets:

https://imos.org.au/news/newsitem/altimeter-wind-and-wave-database-on-aodn/
https://imos.org.au/news/newsitem/new-synthetic-aperture-radar-waves-database-available-through-the-aodn-portal
(currently the most frequently downloaded IMOS datasets)

Papers:

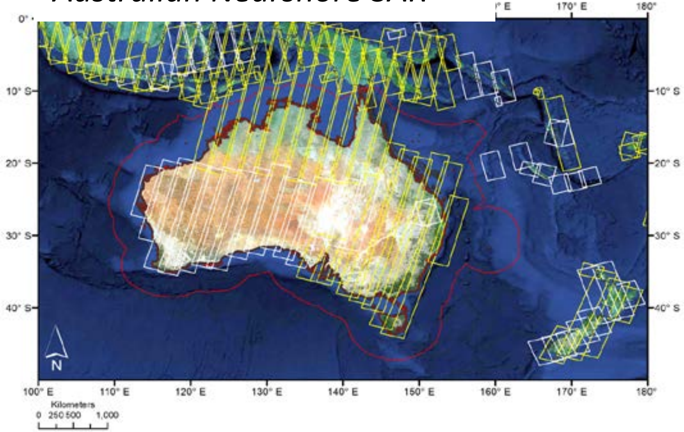
Young & Ribal (2019) Science. DOI: 10.1126/science.aav9527
Ribal & Young (2019) Scientific Data. https://doi.org/10.1038/s41597-019-0083-9
Khan et al. (In Review) JGR-Oceans
Khan et al. (In Review) Geoscientific Data Journal.

Waves – Plans



- Wave buoys (BOM lead; CSIRO and AIMS collaboration): Two new sites as identified by Greenslade et al. (2018) – Eastern Tasmania and Timor Sea.
- Wind speed and direction extension (UoM and CSIRO): Global, multi-mission, scatterometer + coastal HR + Sentinel SAR data. Scatterometer data already available: https://imos.org.au/news/newsitem/scatterometer-wind-database-on-aodn
  Ribal & Young (2020) Remote Sensing. https://doi.org/10.3390/rs12121997
  Ribal & Young (2020) JAOT. https://doi.org/10.1175/JTECH-D-19-0119.1
- Low cost wave buoy project (UWA lead; CSIRO, UniMelb, Deakin, Scripps, Sofar collaboration): Assess performance of moored low-cost wave buoys vs traditional buoys (including mooring effects), emerging tech (SOFAR Spotter buoys, Scripps drifting wave buoys), reliability etc.

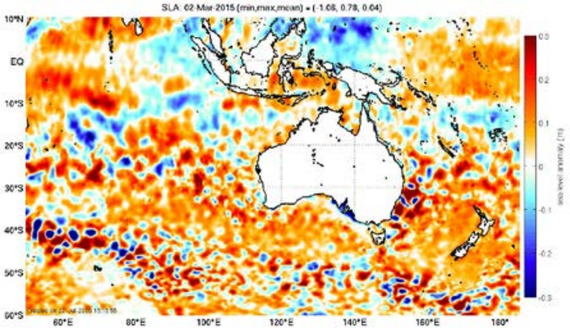
Australian Nearshore SAR

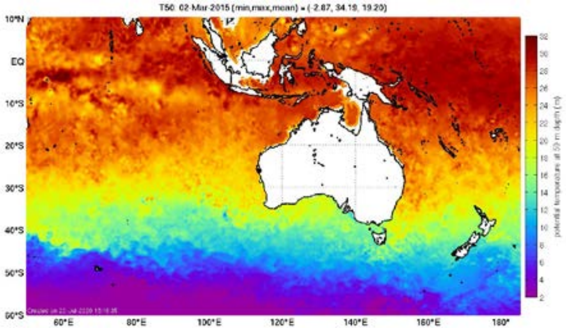


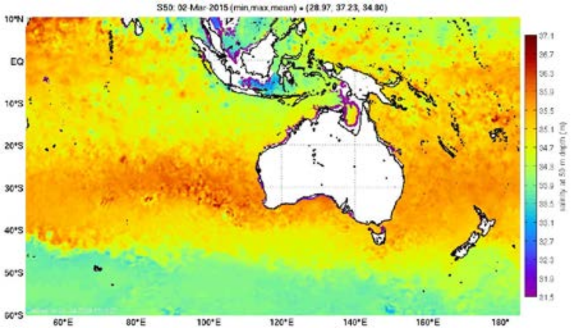
Blue Maps Prototype v1.0

CSIRO lead (Oke et al)

- **Blue Maps** is an observational product that is based on Argo, satellite altimetry, and satellite sea-surface temperature observations (with a heritage from BlueLink).
- To date, weekly maps of SLA, temperature and salinity (50 m, 250 m, and 1000 m depths) between January 2015 to December 2019 are available (http://www.marine.csiro.au/~oke060/Argo/ArgoMaps.html).
- Maps will soon be extended to near-real-time, and maintained a week or so behind real-time thereafter.
- Graphics have been produced for two domains (Australia and the Tasman Sea)







Highlights
WP4: Coastal Altimetry and Preparation for SAR Altimetry

WP4: Coastal / Prep for SAR Altimetry

- An example upwelling event off the Bonney Coast reported in *OceanCurrent*: http://oceancurrent.imos.org.au/news.php#Bonney_Coast_Upwelling_2020
- Good example highlighting the need for SWOT given the agreement of geostrophic shelf velocities and in situ data is relatively poor.

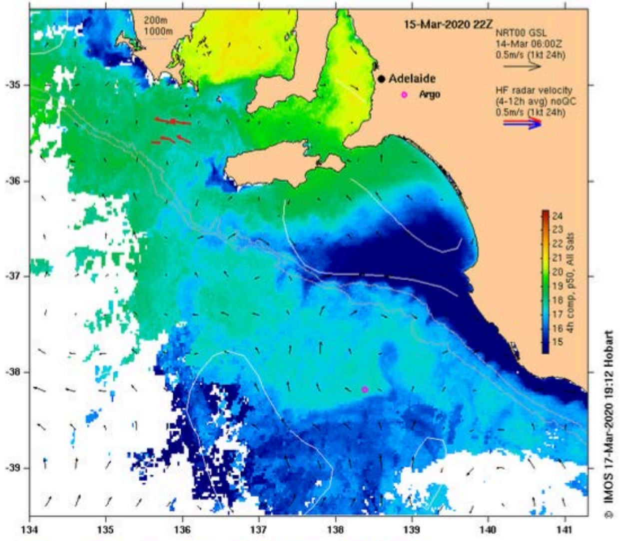


Figure 1. Four-Hour SST at 22:00 15 March 2020 UTC

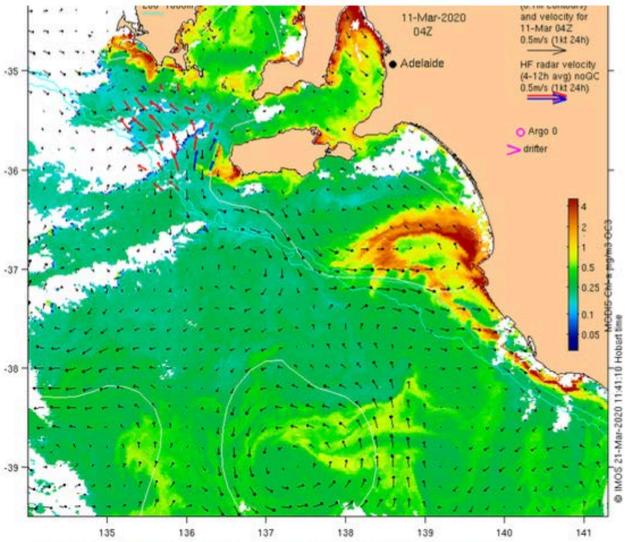
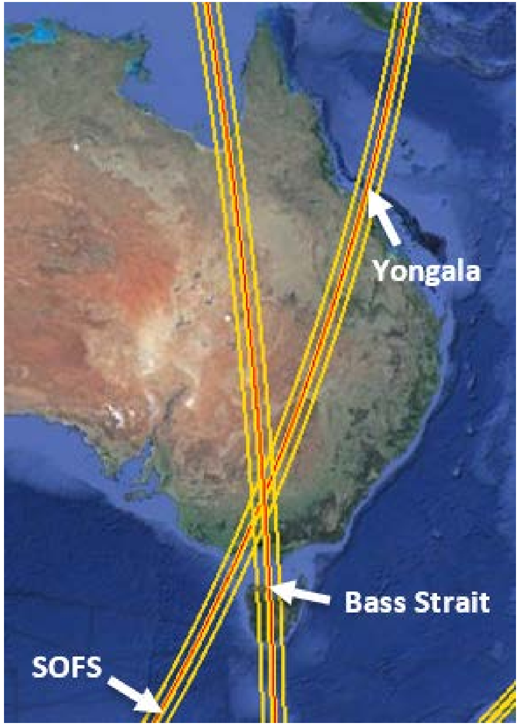


Figure 2. Satellite Chlorophyll-a at 04:00 11 March 2020 UTC

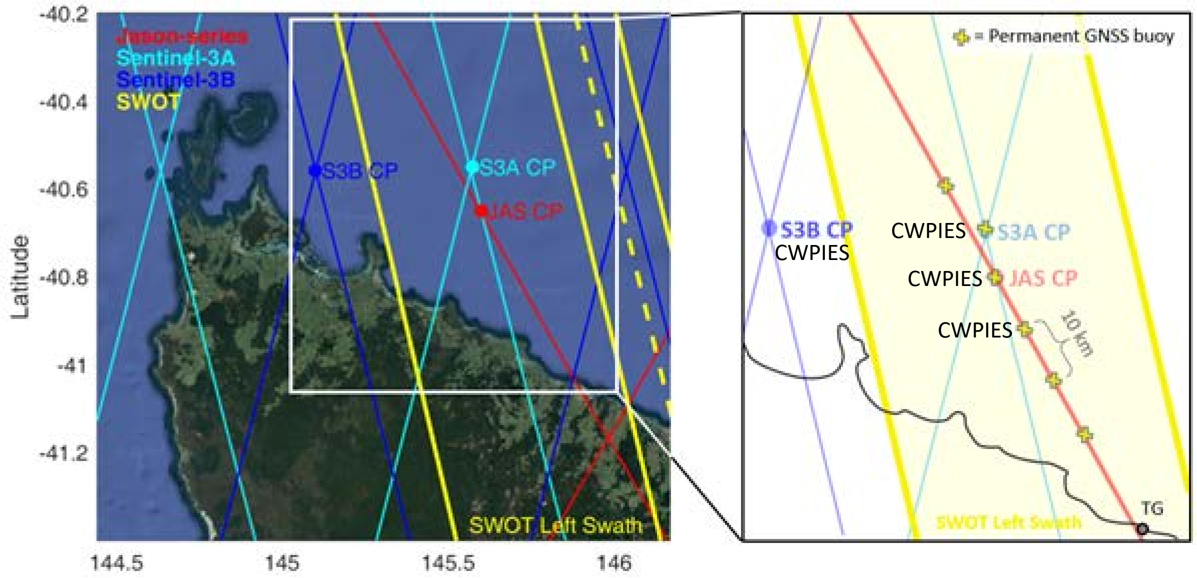
WP4: Coastal / Prep for SAR Altimetry

- Preparations well underway for Sentinel-6 and SWOT validation in the Bass Strait facility.
- Bass Strait is located within the 1-day fast sampling orbit of SWOT.
- Focusing on improved in situ instrumentation (CWPIES and GNSS/INS buoys).
- Developing GNSS equipped instrumentation for SOFS and Yongala as secondary validation targets.



WP4: Coastal / Prep for SAR Altimetry

- Various Sentinel-6 along-track deployments are planned for the cal/val phase. Useful in assisting our understanding of SAR data and as a stepping stone to SWOT.



Salient Results OSTST 2017-2020:

Acknowledgements to the Australian Integrated Marine Observing System (IMOS)

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